

**TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371**

CM1831LM/KL

U.S. APPLICATION NO. (if known, see 37 CFR 1.5)

09/743933

INTERNATIONAL APPLICATION NO.  
PCT/US99/16078

INTERNATIONAL FILING DATE  
16 July 1999

PRIORITY DATE CLAIMED  
20 July 1998

TITLE OF INVENTION

Robotic System

APPLICANT(S) FOR DO/EO/US

BOTTOMLEY, Ian et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information.

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This express request to begin national examination procedures (35 U.S.C. 371(f) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(l).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application was filed (35 U.S.C. 371(c)(2))
  - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☐ has been transmitted by the International Bureau.
  - c. ☒ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
  - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☐ have been transmitted by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.  
☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☐ A substitute specification.
15. ☒ A change of power of attorney and/or address letter.
16. ☐ Other items or information:

"Express Mail" mailing label number

EL 483622426 US

Date of Deposit

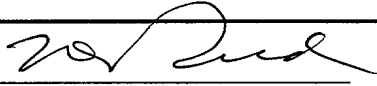
17 January 2001

I hereby certify that this paper/foils being deposited with the United States Postal Service Express Mail Post Office to Addressee service under 37 CFR 1.10 on the date indicated above and is addressed to The Assistant Commissioner of Patents, Washington, D.C. 20231

Administrator Mailing Application

Signature

*Virginia C. Boyd*

U.S. APPLICATION NO. (if known, see 37 CFR 1.51) <b>09/743933</b>		INTERNATIONAL APPLICATION NO. PCT/US99/16078		ATTORNEY'S DOCKET NUMBER CM1831LM/KL	
				CALCULATIONS PTO USE ONLY	
ENTER APPROPRIATE BASIC FEE AMOUNT =				\$710	
Surcharge of \$130.00 for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$0	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total Claims	11-20 =	0	x \$18.00	\$0	
Independent Claims	2-3 =	0	x \$80.00	\$0	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			\$270.00	\$0	
TOTAL OF ABOVE CALCULATIONS =				\$710	
Processing fee of \$130.00 for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$0	
TOTAL NATIONAL FEE =				\$710	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28,3.31). \$40.00 per property +				\$0	
TOTAL FEES ENCLOSED =				\$710	
				Amount to be refunded	\$
				charged	\$
<p>a. [ ] A check in the amount of \$ ____ to cover the above fees is enclosed.</p> <p>b. [ x ] Please charge my Deposit Account No. <u>16-2480</u> in the amount of \$ <u>710</u> to cover the above fees. A duplicate copy of this sheet is enclosed.</p> <p>c. [ x ] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>16-2480</u>. A duplicate copy of this sheet is enclosed.</p> <p>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.</p> <p>SEND ALL CORRESPONDENCE TO:</p>					
L. W. Lewis, Patent Attorney Patent Division – Room E125 The Procter & Gamble Company Beckett Ridge Technical Center 8611 Beckett Road Winchester, OH 45069				 Signature <u>T. David Reed</u> Name <u>32,931</u> Registration Number	

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65  
66  
67  
68  
69  
70  
71  
72  
73  
74  
75  
76  
77  
78  
79  
80  
81  
82  
83  
84  
85  
86  
87  
88  
89  
90  
91  
92  
93  
94  
95  
96  
97  
98  
99  
100  
101  
102  
103  
104  
105  
106  
107  
108  
109  
110  
111  
112  
113  
114  
115  
116  
117  
118  
119  
120  
121  
122  
123  
124  
125  
126  
127  
128  
129  
130  
131  
132  
133  
134  
135  
136  
137  
138  
139  
140  
141  
142  
143  
144  
145  
146  
147  
148  
149  
150  
151  
152  
153  
154  
155  
156  
157  
158  
159  
160  
161  
162  
163  
164  
165  
166  
167  
168  
169  
170  
171  
172  
173  
174  
175  
176  
177  
178  
179  
180  
181  
182  
183  
184  
185  
186  
187  
188  
189  
190  
191  
192  
193  
194  
195  
196  
197  
198  
199  
200  
201  
202  
203  
204  
205  
206  
207  
208  
209  
210  
211  
212  
213  
214  
215  
216  
217  
218  
219  
220  
221  
222  
223  
224  
225  
226  
227  
228  
229  
230  
231  
232  
233  
234  
235  
236  
237  
238  
239  
240  
241  
242  
243  
244  
245  
246  
247  
248  
249  
250  
251  
252  
253  
254  
255  
256  
257  
258  
259  
260  
261  
262  
263  
264  
265  
266  
267  
268  
269  
270  
271  
272  
273  
274  
275  
276  
277  
278  
279  
280  
281  
282  
283  
284  
285  
286  
287  
288  
289  
290  
291  
292  
293  
294  
295  
296  
297  
298  
299  
300  
301  
302  
303  
304  
305  
306  
307  
308  
309  
310  
311  
312  
313  
314  
315  
316  
317  
318  
319  
320  
321  
322  
323  
324  
325  
326  
327  
328  
329  
330  
331  
332  
333  
334  
335  
336  
337  
338  
339  
340  
341  
342  
343  
344  
345  
346  
347  
348  
349  
350  
351  
352  
353  
354  
355  
356  
357  
358  
359  
360  
361  
362  
363  
364  
365  
366  
367  
368  
369  
370  
371  
372  
373  
374  
375  
376  
377  
378  
379  
380  
381  
382  
383  
384  
385  
386  
387  
388  
389  
390  
391  
392  
393  
394  
395  
396  
397  
398  
399  
400  
401  
402  
403  
404  
405  
406  
407  
408  
409  
410  
411  
412  
413  
414  
415  
416  
417  
418  
419  
420  
421  
422  
423  
424  
425  
426  
427  
428  
429  
430  
431  
432  
433  
434  
435  
436  
437  
438  
439  
440  
441  
442  
443  
444  
445  
446  
447  
448  
449  
450  
451  
452  
453  
454  
455  
456  
457  
458  
459  
460  
461  
462  
463  
464  
465  
466  
467  
468  
469  
470  
471  
472  
473  
474  
475  
476  
477  
478  
479  
480  
481  
482  
483  
484  
485  
486  
487  
488  
489  
490  
491  
492  
493  
494  
495  
496  
497  
498  
499  
500  
501  
502  
503  
504  
505  
506  
507  
508  
509  
510  
511  
512  
513  
514  
515  
516  
517  
518  
519  
520  
521  
522  
523  
524  
525  
526  
527  
528  
529  
530  
531  
532  
533  
534  
535  
536  
537  
538  
539  
540  
541  
542  
543  
544  
545  
546  
547  
548  
549  
550  
551  
552  
553  
554  
555  
556  
557  
558  
559  
560  
561  
562  
563  
564  
565  
566  
567  
568  
569  
570  
571  
572  
573  
574  
575  
576  
577  
578  
579  
580  
581  
582  
583  
584  
585  
586  
587  
588  
589  
590  
591  
592  
593  
594  
595  
596  
597  
598  
599  
600  
601  
602  
603  
604  
605  
606  
607  
608  
609  
610  
611  
612  
613  
614  
615  
616  
617  
618  
619  
620  
621  
622  
623  
624  
625  
626  
627  
628  
629  
630  
631  
632  
633  
634  
635  
636  
637  
638  
639  
640  
641  
642  
643  
644  
645  
646  
647  
648  
649  
650  
651  
652  
653  
654  
655  
656  
657  
658  
659  
660  
661  
662  
663  
664  
665  
666  
667  
668  
669  
670  
671  
672  
673  
674  
675  
676  
677  
678  
679  
680  
681  
682  
683  
684  
685  
686  
687  
688  
689  
690  
691  
692  
693  
694  
695  
696  
697  
698  
699  
700  
701  
702  
703  
704  
705  
706  
707  
708  
709  
710  
711  
712  
713  
714  
715  
716  
717  
718  
719  
720  
721  
722  
723  
724  
725  
726  
727  
728  
729  
730  
731  
732  
733  
734  
735  
736  
737  
738  
739  
740  
741  
742  
743  
744  
745  
746  
747  
748  
749  
750  
751  
752  
753  
754  
755  
756  
757  
758  
759  
760  
761  
762  
763  
764  
765  
766  
767  
768  
769  
770  
771  
772  
773  
774  
775  
776  
777  
778  
779  
780  
781  
782  
783  
784  
785  
786  
787  
788  
789  
790  
791  
792  
793  
794  
795  
796  
797  
798  
799  
800  
801  
802  
803  
804  
805  
806  
807  
808  
809  
810  
811  
812  
813  
814  
815  
816  
817  
818  
819  
820  
821  
822  
823  
824  
825  
826  
827  
828  
829  
830  
831  
832  
833  
834  
835  
836  
837  
838  
839  
840  
841  
842  
843  
844  
845  
846  
847  
848  
849  
850  
851  
852  
853  
854  
855  
856  
857  
858  
859  
860  
861  
862  
863  
864  
865  
866  
867  
868  
869  
870  
871  
872  
873  
874  
875  
876  
877  
878  
879  
880  
881  
882  
883  
884  
885  
886  
887  
888  
889  
890  
891  
892  
893  
894  
895  
896  
897  
898  
899  
900  
901  
902  
903  
904  
905  
906  
907  
908  
909  
910  
911  
912  
913  
914  
915  
916  
917  
918  
919  
920  
921  
922  
923  
924  
925  
926  
927  
928  
929  
930  
931  
932  
933  
934  
935  
936  
937  
938  
939  
940  
941  
942  
943  
944  
945  
946  
947  
948  
949  
950  
951  
952  
953  
954  
955  
956  
957  
958  
959  
960  
961  
962  
963  
964  
965  
966  
967  
968  
969  
970  
971  
972  
973  
974  
975  
976  
977  
978  
979  
980  
981  
982  
983  
984  
985  
986  
987  
988  
989  
990  
991  
992  
993  
994  
995  
996  
997  
998  
999  
1000

Case CM-1831ML

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE  
AS DESIGNATED/ELECTED OFFICE FOR INTERNATIONAL APPLICATIONS  
ENTERING THE UNITED STATES NATIONAL PHASE

In the matter of :  
U.S. National Phase Enty :  
Under 35 USC 371 from :  
the International Application of :  
BOTTOMLEY, et al. :  
Int'l Application No. PCT/US 99/16078 :  
Filed in the RO/US on 16 July 1999 :  
Titled: Robotic System :

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents  
Box PCT  
Washington, D.C. 20231

Dear Sir:

Before computing the fees for entering the captioned International Application into the U.S. National Phase, please enter the following amendments **IN THE CLAIMS**:

In Claim 3, delete "or claim 2,".

In Claim 4, replace "any of claims 1 to 3" with -Claim 1--.

In Claim 5, replace "any of claims 1 to 4" with -Claim 1--.

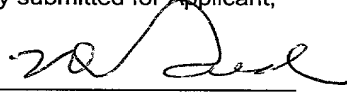
In Claim 7, delete "or claim 6,"

In Claim 11, delete 'or Claim 10,'

The support for these amendments is found in the claims as originally filed. These amendments are being entered to bring the claims into conformance with, *inter alia*, 37 CFR §1.75; no new matter is added.

Respectfully submitted for Applicant,

By:

  
T. David Reed  
Agent for Applicant  
Registration No. 32,931

January 17, 2001  
5299 Spring Grove Avenue  
Cincinnati, Ohio 45217-1087  
Phone: (513) 627-7025  
FAX: (513) 627-6333

## ROBOTIC SYSTEM

The present invention relates to robotic systems and, more particularly to a mobile robotic system capable of movement over a surface and capable of treating the surface.

Conventionally robotic systems, or robots, of this type may be described as semi-autonomous, i.e. self-propelling but relying for navigational guidance on transmitters, receivers and sensors to establish a coordinate system by which the robot navigates, in effect learning the location of obstacles within its field of movement. More recently it has been proposed to allow a robot to move without establishing a coordinate system, instead relying on the sensing of *ad hoc* stimuli to enable the robot to navigate around obstacles. For example, it has been proposed to provide a robotic vacuum cleaner operating along these lines. Self-navigational robotic systems of this type are referred to as autonomous robots.

However, robots of these types, often intended for operation in a domestic environment, need a control system which is capable of allowing the robot to move around its environment in safety and therefore additionally need some sort of collision detection system which is capable of providing information on collisions or impending collisions to a control system capable of acting very quickly to prevent the collision or else to minimise the impact, and to perform collision avoidance by re-orienting the robot before further movement. Unfortunately, on-board processing power is inevitably limited by cost constraints in particular and therefore present systems, to avoid being prohibitively expensive, have relatively limiting navigational abilities which result, in use, in the robot tracing a path which involves passing over the same areas of the surface on plural occasions. Whilst this may not be problematic in say a vacuum cleaner, if the robot has the

function of treating the surface in other ways, then such redundant movement may result in over-treatment of the surface which is not only wasteful of the product used for the treatment (a serious problem where the payload is restricted), but may also damage the surface or otherwise actually be harmful.

The present invention is aimed at providing a self-propelled robot which can overcome such problems.

According to the present invention, there is provided a self-propelled robot for movement over a surface to be treated, the robot comprising

- a power supply;
- a traction mechanism receiving power from the power supply, for moving the robot over the surface;
- a mechanism for controllably depositing a fluent material on to the surface;
- a plurality of navigation sensors providing signals for enabling the robot to navigate over the surface;
- one or more detectors adapted to detect the presence of the material on the surface and provide signals indicative thereof; and
- a control system receiving the signals from the sensors and detectors, for controlling the traction mechanism and the depositing mechanism in dependence upon the signals received from the sensors and detectors.

By detecting the application of the fluent material, which may be a liquid or gaseous fluid or else a flowable powder, the over-application of material can be avoided or minimised by either navigating the robot around areas already treated and/or by controlling the depositing mechanism to stop the deposit of material over such previously treated areas.

Material for treatment is preferably contained within a reservoir on the robot and may comprise suitable compositions for treatment of floors, carpets and other floor coverings. The robot may, if desired, also include

means for cleaning the floor or floor covering prior to treatment, for example in the form of a vacuum cleaning device.

The invention also includes a method of treating a surface using a robot as defined above. The treatment method may be used for various applications on carpets, and other floor coverings, such as cleaning, protective treatment, for example for stain and soil protection, fire protection, UV protection, wear resistance, dust mite control, anti microbial treatment and the like, as well as treatment to provide an aesthetic benefit such as odorization/deodorization. The treatment method may also find application on other surfaces such as synthetic floor coverings, ceramics or wood. As well as polishing hard surfaces, the robot may also be used to apply coatings to either enhance aesthetics or to act as a protective layer.

Thus, according to a further aspect of the invention, there is provided a method for controllably depositing a fluent material on to floors, carpets and other floor coverings using an autonomous, self propelled, deposition-sensing robot. The material deposited may, for example, be a carpet cleaning composition, a hard surface cleaning composition, or one of a number of compositions applied simultaneously, or successively, and may include a marker, the presence of which can be detected to provide detection of the extent of treatment material deposition. Such a marker may have a limited detection life, for example, 12, 24 or 48 hours.

Non-visible treatment may also be provided by the robot of the invention, for example, for odour control, antibacterial action of dust mite control.

The robot preferably comprises a plurality of navigation sensors providing signals for enabling the robot to navigate over the surface, and one or more detectors adapted to detect the presence of the material on the surface and provide signals indicative thereof. The

navigation sensors may include one or more collision sensors and/or proximity sensors. The collision sensors may include one or more lateral displacement sensors arranged on a peripheral sensor ring to provide 360° collision detection, and/or one or more vertical displacement sensors.

Utilising a generally circular shape together with a control regime which scans for the best direction of escape after the robot has become stuck (say in a corner) is especially advantageous. Furthermore, it may be additionally advantageous to detect the angle of any collision, in order to optimise the robots subsequent angle of movement away from the obstacle.

The traction mechanism preferably includes left and right, coaxially disposed drive wheels with corresponding drive motors which are preferably provided with pulse-width modulated drive signals.

For depositing material on the surface, an array of delivery ports, e.g. spray nozzles, may extend generally parallel with the drive wheel axis, preferably extending to the same lateral extent as the deposition detectors.

The detectors may comprise one or more sensors arranged to detect the edge of a section of previously deposited product. Suitable deposition detectors include one or more radiation sources and/or detectors, moisture detectors, reflectivity meters, conductivity meters etc. Detectors may be disposed laterally of the drive wheels, preferably forward thereof.

The robot further preferably comprises a control system for controlling deposition of the material dependent on the signals received from the one or more detectors and sensors. In preferred embodiments, the control system functions to control deposition of the material (e.g. to avoid or minimise over-application) by a combination of strategies comprising a) navigating the robot around previously-treated areas of the surface (referred to herein

as the 'navigation strategy'; and b) controlling the depositing mechanism to stop or reduce the deposit of fluent material on to the surface as the robot passes over such previously-treated areas (referred to herein as the 'deposition rate control strategy'). In practice, the control system arbitrates between the two strategies depending on the signals received from the navigation sensors and deposition detectors. The ability of the control system to arbitrate between the two strategies, for example to make a rapid judgment on whether to cross or navigate around previously-treated areas and whether to maintain, reduce or stop deposition accordingly, is an important feature for ensuring controlled deposition in the context of a fully autonomous robot designed to operate in the cluttered, unstructured and track-free environment typically found in domestic and institutional situations.

Alternatively, the control system can be designed to control deposition purely following a deposition rate control strategy, in other words, by controlling the depositing mechanism to stop or reduce the deposit of fluent material on to the surface as the robot passes over previously-treated areas. Of course, systems depending purely on deposition rate control require less complicated electronics than the preferred combined-strategy systems described above. On the other hand, single strategy systems can be less efficient in terms of the time required to complete the task in hand.

Preferably, the control system has a hierarchical architecture and includes one or more microprocessor controllers or microcontrollers for controlling higher-level functions, and providing higher-level instructions and a plurality of lower-level function modules adapted to receive signals from the sensors and detectors and to provide control signals in response thereto. The traction mechanism and product dispensing control signals are preferably issued to a traction mechanism controller and to



a product dispensing controller via a manifold or bus arranged to receive signal inputs from the microprocessor and a plurality of sub-processors each corresponding to a respective navigation sensor or the like. By this means, a distributed processing system can be employed to provide a high level of flexibility in control strategy, whilst allowing simple connection of the sub-processors, thus to reduce the complexity and expense of the control system. The various processors preferably include neural network functionality to provide behavioural characteristics appropriate to the chosen task of the robot, the behavioural characteristics of the processors preferably being moderated by a group of generic moderators providing necessary arbitration between the control instructions from the various processors. The higher-level functions preferably include one or more functions selected from determination of the robot being stuck, room size estimation, clutter level determination, and battery monitoring. The lower-level modules are preferably analog neural networks which provide, for example, edge follow and dispense control functions, together, preferably, with cliff sensing, collision detection, speed reduction and random movement functions.

One example of a self-propelled robot constructed in accordance with the present invention, and its method of operation, will now be described with reference to the accompanying drawings in which:-

Figure 1 is an underneath plan view of the robot;

Figure 2 is a functional diagram of the robot; and

Figures 3A-C illustrate neural net aspects of part of the robot's control system.

As can be seen from Figure 1, the robot of the present example is substantially circular in overall plan view. A simple plate-like chassis 1 supports both the mechanical and electrical components of the robot. The plate-like chassis 1 supports the body 2 of the robot on resilient

rubber mountings 3 which allow the body to move relative to the chassis when a force is applied, eg by collision with an object, to a sensor ring 20 which is disposed around the periphery of the body. Four displacement sensors 4 placed at 90° intervals around the robot measure lateral displacement of the body 2 relative to the chassis 1 and inform the control system of contact with an external object. The displacement sensors 4 are based on linear Hall Effect devices which produce a voltage which is proportional to the strength of the magnetic field in which they immersed. Each sensor consists of a small permanent magnet mounted on the body shell support ring 20 and a Hall Effect device mounted on the main chassis 1. When the body moves with respect to the chassis (as happens during a collision) the voltage produced by the Hall Effect device varies and can be used to signal the control system that an object has been encountered. By examining the signals from all four sensors the angle and magnitude of the collision can be deduced. These sensors allow displacements in the order of 0.1 mm to be reliably detected. A fifth sensor 18, of the same type as the displacement sensors 4, measures vertical displacement of the body shell to accommodate forces produced by objects which are of insufficient height to cause lateral body movement. In an alternative construction, these sensors may be superseded by a single custom-built sensor which can measure lateral and vertical displacement simultaneously. Such an integrated sensor may be optical in nature utilising an array of photo detectors mounted on the chassis and a light source which is mounted on the body support ring.

A single forward facing time-of-flight ultrasound sensor 13 is mounted at the front of the robot and is used to allow the robot to gather more information regarding its surroundings than can be achieved by the displacement sensors 4 alone. This ultrasound sensor 13 is based on a Polaroid® ranging module Polaroid 6500 series sonar ranging

device, Polaroid reference 615077, the data from which is pre-processed by a dedicated unit 5 on which the sensor 13 is located. An ultrasonic sensor unit 5, containing the ultrasonic sensor 13 itself and a suitable electronic interface, are mounted on the body to provide proximity information to the robot's control system.

Left and right motors 6, 7 are provided to drive corresponding left and right wheels 8, 9 each with a soft rubber tyre, via an integral reduction gearbox, to provide motive power to the robot. A single castor 10 mounted at the rear of the robot completes the drive/movement system and allows the chassis to move forwards or backwards and rotate on the spot. Varying the rotational speed of the left and right motors 6, 7 allows the robot to be steered in any direction. The speed of the motors is controlled by pulse width modulating the voltages applied to the motors. This involves switching the motor current on and off very rapidly (100,000 times a second) and varying the ratio of 'on' time to 'off' time. This is a very efficient way to control the power to the motors and hence their speed.

Power for the robot, including the motors 6, 7 and the control system is provided by means of a battery pack 11 mounted on the chassis 1. To protect the components of the robot from tampering and from damage a cover or housing (not shown) is attached to the body 2 to house the robot components. In the preferred embodiment, this is part-spherical or dome-like in shape.

A row of spray nozzles 16 and a pump 115 (not shown in Figure 1) provide a means of dispensing treating fluid on to the surface to be treated and detectors 14,15,17 are provided to detect the presence of the treating fluid (or a suitable additional marker fluid). The three sensor units 14, 15, 17, one placed in front of each of the drive wheels and the third 17 placed centrally, emit light at a wavelength which excites a fluorescent dye in the product being detected. These sensor units incorporate a pair of

light sensitive devices positioned at 90° to the robot's direction of travel and spaced 20mm apart, which can detect light produced by the fluorescent dye. By examining the intensity of the light detected by these devices the edge of a section of previously deposited product can be detected and hence followed. In an alternative construction, the three sensor units 14, 15, 17 pass a small electrical current through the floor covering by virtue of an array of stainless steel contacts which are designed to glide over the floor covering surface. The conductivity of the floor covering will vary depending upon whether or not it has recently been sprayed with product. By examining the conductivity of the floor covering, the edge of previously deposited product can be detected and hence followed.

In an alternative construction, in which fluid is to be dispensed to an edge or corner, the positioning of the sprays is modified. The modification is such that the spray is able to dispense to the edge of the robot or beyond, for example, either by positioning nozzles at the very periphery of the underside or by additional nozzles which protrude from the casing and are directed such that they spray beyond the perimeter of the robot.

The robot's control system comprises various circuit boards and components which are not shown in Figure 1 in detail, but which are broadly indicated by reference numerals 12 in Figure 1.

The control system will now be described in further detail.

Two purposes of the control system of an autonomous mobile robot such as that of the example are to allow the robot to move within a physical environment in safety and to enable it to perform useful tasks. To do this the robot must be aware of its immediate surroundings and be able to react to particular circumstances in particular ways. A robot intended for an unconstrained domestic environment

needs to have certain basic skills, such as a collision detection skill, which might cause it to stop upon collision with an object and then take evasive action before resuming its previous activity.

In the case of collision detection, the sensors 4, 18, 13, which sense impacts with and proximity to objects, will inform the control system of the angle of impact and its force. The control system must react very quickly to this stimulus and prevent any further motion in this direction. A conventional approach to this problem would be to have a computer monitor the collision sensors and act upon the data to stop the motors and then perform some form of avoidance manoeuvre. This is perfectly feasible, but if the same computer is required simultaneously to perform other tasks, for example, such as in the present case, monitoring other sensors and performing navigational mathematics, it soon reaches a point where the speed and power of the on-board computer required becomes prohibitively expensive if reaction times are to be acceptable.

The alternative, adopted in the present invention, is to use discrete modules that perform functions in a way analogous to the reflexes of a biological organism. The advantage of this system are obvious: the main processor can merely issue high level commands such as move or turn and is left free to perform other abstract tasks.

This alternative is a form of hierarchical distributed processing and allows the control system to be composed of simple modules that together yield faster response times than a non-distributed system of the same cost. Another significant advantage of distributed processing is its inherent robustness. If a system employing a conventional single processor approach suffers a failure, it can leave the system in an unsafe state, which in the case of a robot might allow it to crash into objects or people. The distributed approach can be designed so as to have a much

greater degree of fault tolerance, rendering the occurrence of complete system failures much less likely.

Distributed processing can be implemented using conventional computers connected together by some form of network, but these tend to be expensive to design and implement. The approach adopted in the present invention is to simulate biological neural networks in real analogue hardware to provide a system that consists of behavioural modules, which are designed to perform individual tasks. These behaviours are managed by a simple micro controller, which performs higher level tasks such as mathematical functions to estimate room size or a strategy for escaping from under a table.

The control system 100 will now be described with reference to Figures 2 and 3. Figure 2 illustrates the functional relationship of the control system components.

The control behaviours used on the robot can be divided into two basic types, Low Level and High Level. Low Level behaviours are implemented in hardware as discrete neural blocks or modules 101-105, while High Level behaviours are software algorithms running on a micro controller 106.

The functions of the Low level behaviour modules 101-105 are now described in detail:-

**Cliff** - To prevent the robot falling down stairs it is equipped with four cliff detectors 21 which warn of vertical hazards and provide signals to the cliff behaviour module 101. The cliff detectors 21 are active infra red proximity sensors which comprise a modulated light source which emits a beam of infra red light directed at the target (in this case the floor), and an infra red detector which monitors the intensity of the light which is reflected. When the sensor is directed over a cliff the intensity of the reflected light decreases and the sensor informs the control system of the hazard. This behavioural function has

very high priority and when active operates to manoeuvre the robot away from the hazard and return it to a course which is modified to avoid cliff type drops.

**Edge Follow** - The Edge Follow module 104 provides a behavioural function which uses information from the sensors 14,15,17 which allow the robot to find the edge of a previously treated area (as described above) and to travel along that edge to produce a faster scan of the floor surface.

**Random** - In the absence of any edges the robot moves in a random direction under the action of a random movement module 114 until an object is encountered or the edge follow behaviour is activated.

**Collide** - The collision detection module 102 takes input from the displacement sensors 4,18 and operates so that upon encountering an obstacle the robot stops, reverses a small distance, then turns away from the object in a direction that depends upon the angle of impact, which is determined from the signals of the displacement sensors 4,18.

**Reduce Speed** - When an object is detected by the ultrasound sensor unit 5 within a pre-set range limit, the forward speed of the robot is reduced by the Reduce Speed module 103 to minimise the impact force generated when contact with the object occurs.

**Dispense** - A dispense control module 105 has inputs from a fluid level sensor 203 and sensors 14, 15, 17 via the Edge Follow module 104. If the UV sensors 14, 15, 17 report untreated carpet in the direction of travel the treatment chemical is dispensed until treated areas are encountered or fluid level reaches a lower limit.

High level behaviours are determined within the microcontroller 106 and comprise the following functional modules:-

**Stuck** - A routine 107 determines if there have been more than a chosen number of collisions in a select period and causes the robot to stop and use the ultrasound range finder 5, 13 to find the longest clear path and move in that direction. The robot will rotate on the spot, by operating the wheels 8, 9 in opposite directions, looking for the longest clear path. When the best direction is discovered the robot will move off in that direction.

**Estimate Room size** - By using statistics gathered from the ultrasound sensor 13 and measuring the time between collisions the routine 108 is able to estimate the area of the room. This is used to determine how long the robot should take to treat a particular room.

**Estimate clutter level** - By comparing estimates of room size against collisions per minute a routine 109 is able to deduce a factor describing the complexity of the room. This can then be used to modify the run time to allow for the level of clutter.

**Battery Monitor** - A battery monitor routine 110 checks the state of the battery by monitoring the output voltage and current. It uses this information to estimate how long the battery will be able to support the robot's systems before a re-charge is needed. When the monitor routine decides that the battery state is approaching the point where reliable operation is no longer possible, the user is warned by illumination of a battery low indicator. If the robot is allowed to continue to operate without being re-charged the monitor routine will shut the robot down in a safe and controlled fashion when power levels reach a predetermined point. Nickel Cadmium or Nickel Metal Hydride batteries require careful charging to ensure maximum capacity and life span and the monitor routine also controls the charging cycle of the battery to ensure that these needs are met.



Traditionally neural network designers have insisted that every neuron in a network is connected to every other neuron in that network. Whilst this allows the network the greatest level of flexibility, very many (even as high as 90%) of these connections will never be used. The present system allows pre-configured neural networks to be connected together in a much less complex way allowing the behaviour of the robot to dynamically adjust to the immediate environment in a continuous fashion.

This so-called "Manifold Architecture" comprises an analogue bus or manifold 111, connecting all the behaviour modules 101-105 and their associated actuators to each other. Four generic moderators arbitrate between the behaviours, and give rise to a prototype behaviour of their own which regulates the overall activity of the robot via a motor controller 112 and dispensing fluid pump controller 113 driving the pump 115. These generic moderators sum all the excitatory and inhibitory inputs and apply a non-linear transfer function to the results. The outputs from these moderators form the inputs to the motor controllers.

In order to explain the function of the manifold architecture, it is necessary to describe the basic neural aspects of the control system. Figures 3A-C will be referenced for this purpose.

A single neuron (see Fig. 3A) has three basic types of connections, excitatory inputs which cause the neuron to 'fire', inhibitory inputs which suppress activity and the output which represents the state of the neuron. Additionally neurons may have other properties such as Decay which causes the output to fall slowly over time, and Threshold which suppresses all output until the sum of all the input exceeds a certain level.

Figure 3B shows (by way of example) a simplified representation of the collide behaviour and the manifold system in neural notation.

The collision sensors 4 are represented in Fig. 3B as 1, 2, 3 and 4 and are buffered and normalised by sensor pre-processors 5, 6, 7 and 8. The outputs of the sensor pre-processors are each fed into a single neuron 9, 10, 11 and 12 configured as a pulse stretcher with a time constant of approximately 5 seconds. The outputs of these neurons are connected to the rest of the network formed by neurons 13 to 28 where the pattern of connections, and transfer characteristics of the neurons give rise to the behaviour itself. The outputs of this network are connected via the connections 41 to 48 to the manifold summators (generic moderators) 29 to 32 where the signals are summed and the outputs 37 to 40 form the inputs to the left and right motor controllers (not shown in this figure). Connections from another unspecified behaviour (of which there may be many) are shown as 50 to 57. Connection 49 is a subsumption input, which is used to disable the entire behaviour under control of the scheduler software running on a microcontroller or another higher priority neural behaviour. The sensor outputs are also made available to the microcontroller so that high level behaviours such as clutter level estimation may have access to any data produced.

In the event of a direct collision whilst travelling straight ahead the following is true:

The front collision sensor 1 produces a pulse as contact with an obstacle occurs. This pulse is amplified by the sensor pre-processing element 5 and passed to the input neuron 9. This neuron is configured to stretch the width of an input pulse (when that pulse exceeds a predetermined input threshold) to approximately 5 seconds. The output from the input neuron 9 is simultaneously fed to four other neurons 13, 14, 15 and 16. These 'hidden layer' neurons are configured to act as attenuators or in neural terms 'weights', and therefore change the

amplitude of the applied signals. Neurons 13 and 15 are set to produce an output level of 10 (maximum) when excited and the outputs are connected to the output neurons 22 and 26 which when excited apply signals to the manifold instructing the motors to stop moving forward. Neurons 14 and 16 are set to produce an output of 5 (half) when excited and their outputs are connected to the output neurons 23 and 27 which when excited apply signals to the manifold instructing the motors to move the robot backwards. This part of the behaviour itself, would theoretically lead to a situation where the robot would repeatedly collide and retreat in a straight line from an obstacle, but inherent inaccuracies in the control system and drive mechanics coupled with the fact that the probability of a perfect head on collision is remote, means that the other collision strategies which involve the left and right sensors, will cause the robot to turn as it reverses from an obstacle and produces a useful behaviour.

The manifold function will now be described in detail with reference to Fig. 3C. The manifold as its name implies brings together all the output from the robots various neural behaviours, sums it together and provides the inputs to the motor controllers. Fig. 3C shows the section which controls the right hand motor controller; the left hand section is identical.

Connection 41 is effectively the 'Go forward right' input and 42 is 'Don't go forward right'. These two opposing inputs are fed into the excitatory and inhibitory inputs of neuron 29. If values of Go forward 6 and don't go forward 3 are applied simultaneously, neuron 29 outputs a value of 3, but if the values are reversed ie. Go forward 3 and don't go forward 6, neuron 29 produces 0. This is most important as it allows a behaviour to inhibit motion

in a particular direction without causing motion in the opposite direction.

Neuron 30 performs the same task as 29 except it's inputs are 'Go backwards' 43 and 'Don't go backwards' 44.

Neuron 29 is connected to the excitatory input of 33 which in turn drives the 'Go forward' input of the right hand motor controller via connection 37. Neurons 30 and 34 are connected to the 'Go backward' input of the right hand motor controller via connection 38. The motor controller sums these inputs so that Go forward 8 and Go Backward 4 simultaneously applied on connections 37 and 38 respectively will result in the right wheel rotating forward at a speed of 4.

Neurons 33 and 34 also have inhibitory connections where the forward signal path is connected to the reverse path and vice versa. This allows non-linear behaviour of the manifold and as the strength of these connections is increased, the robot becomes less likely to enter a stable state, where no motion occurs due to behaviours with conflicting interests asserting themselves simultaneously.

Further details of some of the various sensors and their operation will now be given:-

The ultrasound sensor unit 5 has a pre-processor which manages the sensor 13, providing timing pulses etc., and provides the high level behaviour with continuous 'range to target' data and a simple range warning to the reduce speed behaviour module 103. The continuous output is used by the stuck behaviour module 107 which rotates the robot through 360° whilst looking for a clear path down which the robot can escape and is also used by the room size and clutter estimation behaviour modules 109, 108.

To perform the task of dispensing the treatment compositions (for example, a carpet cleaning formulation, known *per se*, comprising of an aqueous solution of anionic surfactant, optionally together with a polycarboxylate soil

suspending agent) on to a surface, it is desirable to know which areas of the surface have already been treated.

A marker agent, added to the formulation in question, has characteristic properties such as absorption or emission of light at a known frequency, or fluorescent behaviour which can be detected by the robot. Examples of such markers are luminol, which can be made to react with hydrogen peroxide to emit light, and substituted coumarins such as 7-hydroxy or 4-methyl-7-hydroxy variants which are highly fluorescent but undergo ring opening reactions to form a non-fluorescent derivative.

For detection purposes, a light source and corresponding photodiode detectors 14, 15, 17 are placed left and right in front of the drive wheels 6,7 of the robot in order to detect said marker chemical and enable the control system to follow the edge of a previous pass. In this manner, a structured dispensing pattern can be established. Moreover, the detector can be linked, via a negative feedback system, to the dispensing array, thereby to avoid the deposition of formulation on to an area of surface that has already been treated. When no area of the floor can be found that has not been treated, the actual time taken is compared with data provided by the estimated room size behaviour module 108, and if the two are within acceptable limits, the treatment of the floor is deemed complete. The characteristic properties by which the marker is detected either decay within 24-48 hours of application (by aerial oxidation or photolytic decomposition) or, in the case of a two stage treatment method, a second chemical may be applied over the first, neutralising the characteristic properties of the marker chemical.

An alternative means of achieving this desired behaviour is to use moisture detection to identify areas of the surface which have already been treated. In this case, the inherent moisture of a liquid formulation is used to

detect treated surfaces via moisture sensing arrays which are positioned left and right in front of the drive wheels 6,7 of the robot. Again, this system can be used to enable the robot to follow the edge of a previous pass.

In cases where a hard floor surface is being treated (for example with an aqueous cleaning formulation comprising a mid chain-length non-ionic surfactant with carbonate citrate and caustic soda) the reflective properties of the floor may be used to detect which areas of floor have been treated. A high intensity light source directs light on to the floor where, following reflection, it is subsequently detected by a photodiode detector. These are positioned left and right in front of the drive wheels 6,7 of the robot. Again, this system can be used to enable the robot to follow the edge of a previous pass. In this case, the ability of a formulation to reduce the reflectivity of the floor is harnessed to enable its detection.

**What is claimed is:**

1. A self-propelled robot for movement over a surface to be treated, the robot comprising
  - a power supply (11);
  - a traction mechanism (6-9) receiving power from the power supply, for moving the robot over the surface;
  - a mechanism (16) for controllably depositing a fluent material on to the surface;
  - a plurality of navigation sensors (4,13,18,21) providing signals for enabling the robot to navigate over the surface;
  - one or more detectors adapted (14,15,17) to detect the presence of the material on the surface and provide signals indicative thereof; and
  - a control system (12,100) receiving the signals from the sensors and detectors, for controlling the traction mechanism and the depositing mechanism in dependence upon the signals received from the sensors and detectors.
2. A robot according to claim 1, wherein the navigation sensors include collision sensors comprising one or more lateral displacement sensors (4) arranged on a peripheral sensor ring (20) to provide 360° collision detection, and/or one or more vertical displacement sensors (18).
3. A robot according to claim 1 or claim 2, wherein the detectors comprise one or more sensors (14,15) arranged to detect the edge of a section of previously deposited product.
4. A robot according to any of claims 1 to 3, wherein the deposition detectors include one or more radiation sources and/or detectors, moisture detectors, reflectivity meters, conductivity meters.

5. A robot according to any of claims 1 to 4, wherein the control system (100) has a hierarchical architecture and includes one or more microprocessor controllers or microcontrollers (106) for controlling higher-level functions and providing higher-level instructions; and a plurality of lower-level function modules (101-104,114) adapted to receive signals from the sensors and detectors (4,13-15,17,18,21) and having processors to provide control signals in response thereto.

6. A robot according to claim 5, wherein the traction mechanism and product dispensing control signals are issued to a traction mechanism controller (112) and to a product dispensing controller (113) via a manifold or bus (111) arranged to receive signal inputs from the microprocessor(s) or microcontroller(s) (106) and from the lower-level function modules (101-104).

7. A robot according to claim 5 or claim 6, wherein the lower level function module processors (101-104,114) include neural network functionality to provide behavioural characteristics appropriate to the chosen task of the robot, the behavioural characteristics of the processors being moderated by a group of generic moderators (111,29-32) providing arbitration between the control instructions from the various processors (101-104,114).

8. A robot according to claim 7, wherein the lower-level modules (101-104,114) comprise analog neural networks which provide functions selected from edge follow and dispense control functions, cliff sensing, collision detection, speed reduction and random movement functions.



9. A method for controllably depositing a fluent material on to floors, carpets and other floor coverings using an autonomous, self propelled, deposition-sensing and deposition rate-controlling robot.

10. A method according to claim 9, wherein the material deposited is a carpet cleaning composition, an odorization/deodorization composition, a dust mite control composition, an anti-microbial composition, a hard surface cleaning composition, or one of a number of compositions applied simultaneously, or successively.

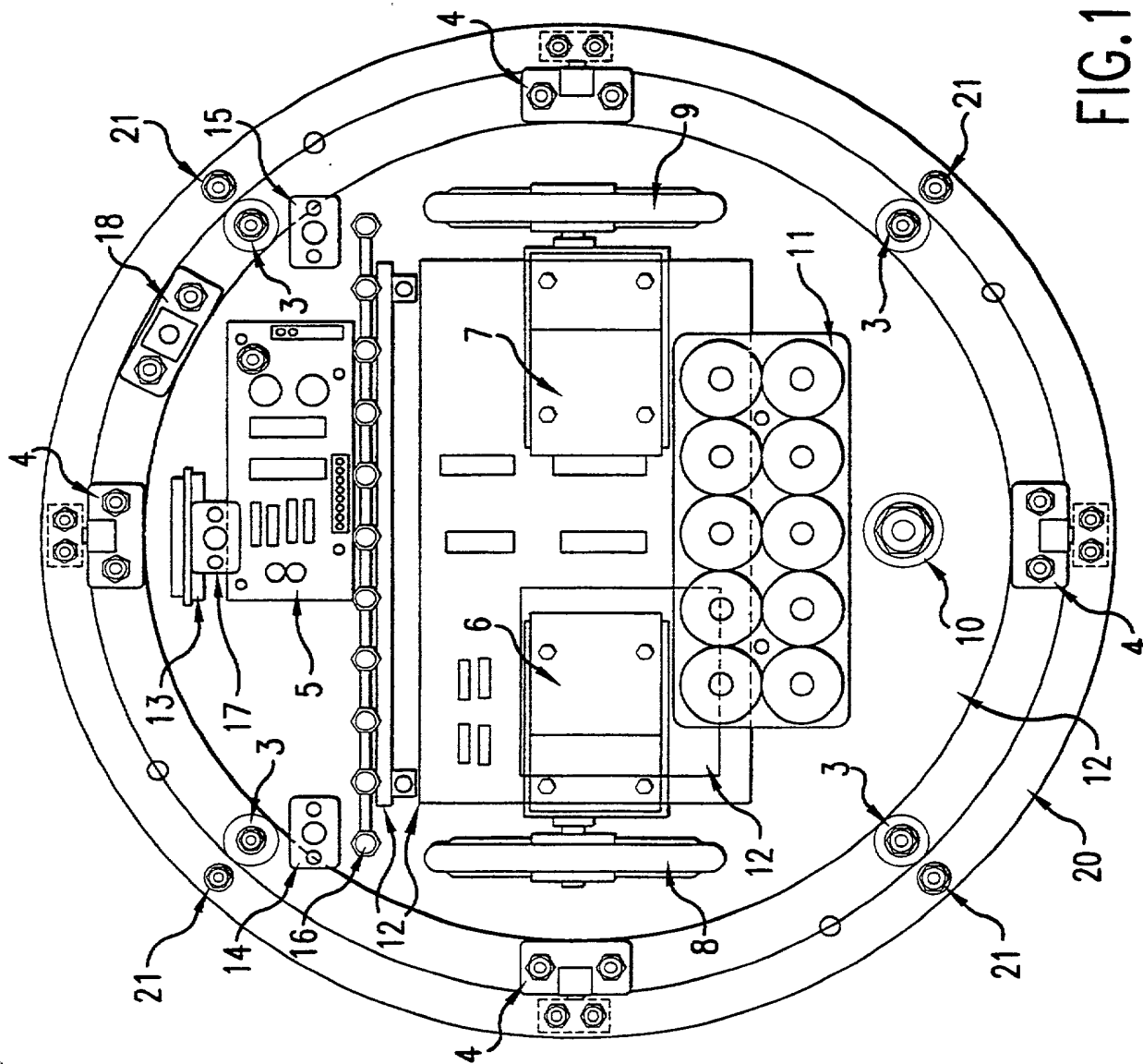
11. A method according to claim 9 or claim 10, wherein the material deposited includes a marker, the presence of which can be detected to provide detection of the extent of treatment material deposition.

PCT/US 99/16 078

RO/US 10 SEP 1999

1/3

FIG. 1



AMENDED SHEET

PCT/US 99/16 078

2/3

RO/US 10 SEP 1999/

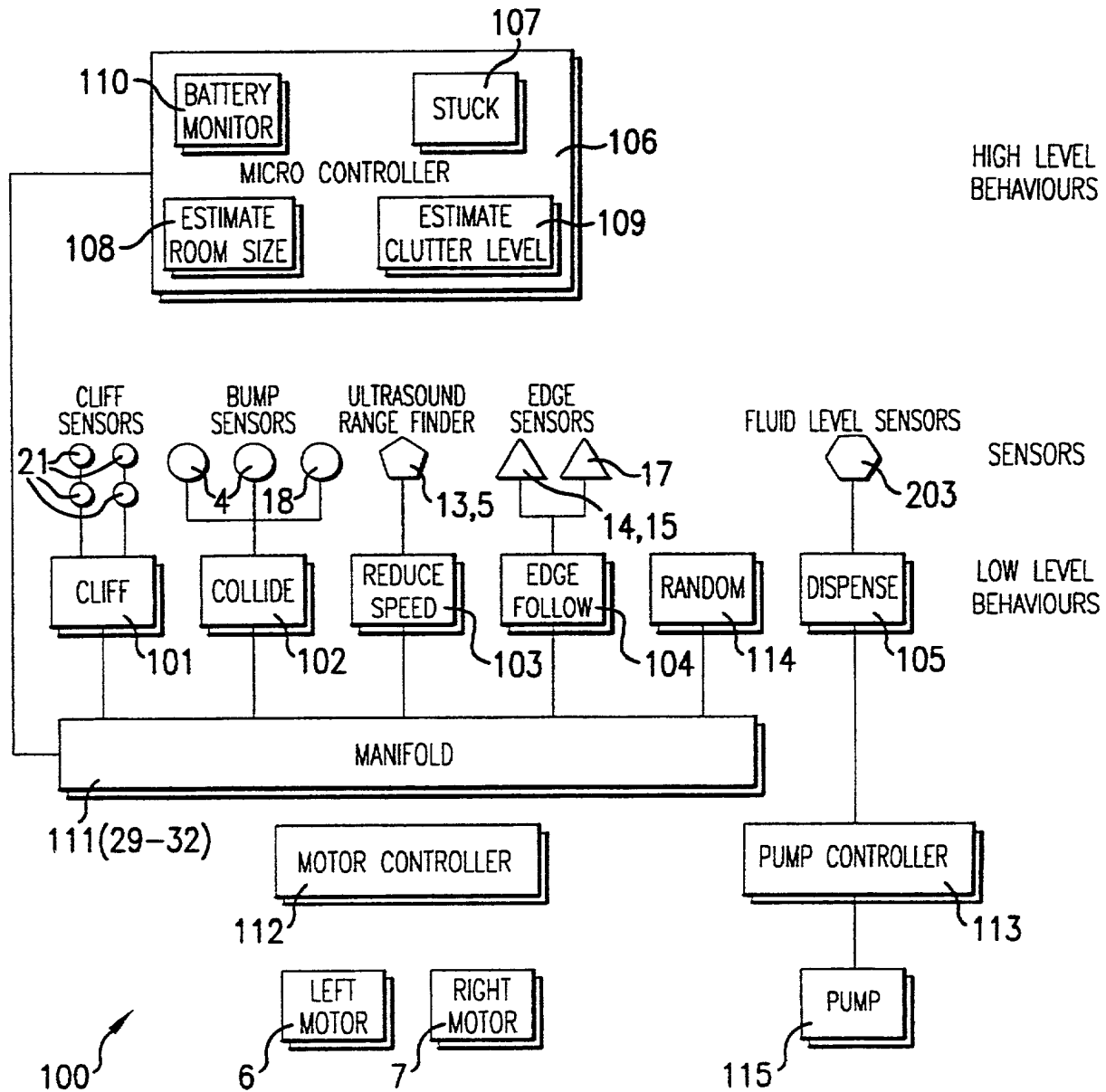


FIG.2

PCT/US 99/16 078

3/3

RO/US 10 SEP 1999

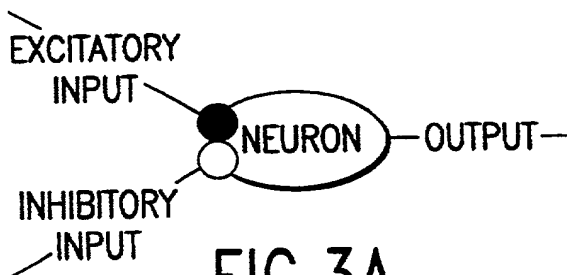


FIG. 3A

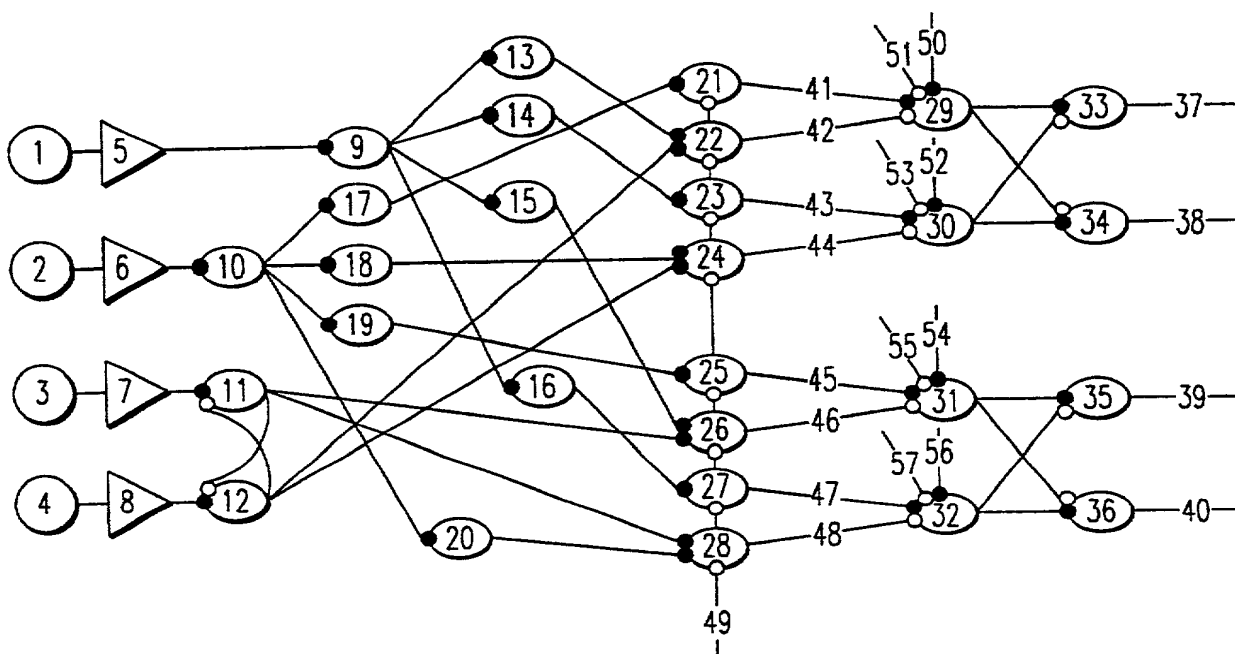


FIG. 3B

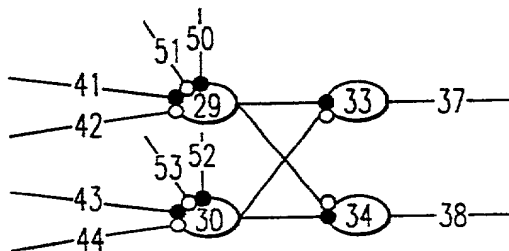


FIG. 3C

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the U.S. National Phase Entry  
Under 35 USC 371 from  
International Application of  
BOTTOMLEY, Ian et al.  
Int'l. Application No. PCT/US99/16078  
Filed in the RO/US on 16 July 1999  
Entitled: *Robotic System*

ASSOCIATE POWER OF ATTORNEY

Assistant Commissioner for Patents  
Box PCT  
Washington, D.C. 20231

Dear Sir:


You are requested to recognize L. W. Lewis (Registration No. 30,769), L. L. Huston (Registration No. 32,994), T. J. Osborne (Registration No. 39,796), and A. M. Stone (Registration No. 41,335) of The Procter & Gamble Company, Cincinnati, Ohio, as Associate Attorney to prosecute this application, to make alterations and amendments therein, and to transact all business in the Patent Office connected with the application or with the patent granted thereupon.

Please address all future communications to:

L. W. Lewis, Patent Attorney  
Patent Division – Room E125  
The Procter & Gamble Company  
Beckett Ridge Technical Center  
8611 Beckett Road  
Winchester, OH 45069

Respectfully submitted for Applicants,

By

  
T. David Reed  
Agent for Applicant  
Registration No. 32,931

Cincinnati, Ohio  
15 January 2001  
(513) 627-7025/FAX 627-6333  
poabr

## DECLARATION COMBINED WITH POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

"Robotic System"

bearing the above listed Procter & Gamble Company Case number, the specification of which was filed as PCT/US99/16078, designating at least the United States of America, with the United States Receiving Office on 16 July 1999.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37 Code of Federal Regulations §1.56.

I hereby claim foreign priority benefits under Title 35 United States Code §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application for patent or Inventor's certificate having a filing date before that of the application on which priority is claimed:

PRIOR FOREIGN APPLICATION(S) TO WHICH WE CLAIM PRIORITY:

98305761.3                      EP                      20 July 1998

I hereby claim the benefit under Title 35 United States Code §120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35 United States Code §112, I acknowledge the duty to disclose material information as defined in Title 37 Code of Federal Regulations §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Appln. Serial No.	Filing Date	Status - patented, pending, abandoned
Appln. Serial No.	Filing Date	Status - patented, pending, abandoned

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the U.S. National Phase Entry  
Under 35 USC 371 from  
International Application of  
BOTTOMLEY, Ian et al.  
Int'l. Application No. PCT/US99/16078  
Filed in the RO/US on 16 July 1999  
Entitled: *Robotic System*

ASSOCIATE POWER OF ATTORNEY

Assistant Commissioner for Patents  
Box PCT  
Washington, D.C. 20231

Dear Sir:

You are requested to recognize L. W. Lewis (Registration No. 30,769), L. L. Huston (Registration No. 32,994), P. M. Ulrich (Registration No. 46,404), and A. M. Stone (Registration No. 41,335) of The Procter & Gamble Company, Cincinnati, Ohio, as Associate Attorney to prosecute this application, to make alterations and amendments therein, and to transact all business in the Patent Office connected with the application or with the patent granted thereupon.

Please address all future communications to:

P. M. Ulrich, Patent Attorney  
Patent Division – Room E125  
The Procter & Gamble Company  
Beckett Ridge Technical Center  
8611 Beckett Road  
Winchester, OH 45069

Respectfully submitted for Applicants,

By



T. David Reed  
Agent for Applicant  
Registration No. 32,931

Cincinnati, Ohio  
14 February 2001  
(513) 627-7025/FAX 627-6333  
poabr

I hereby appoint the following as my attorney(s) or agent(s) with full power of substitution to prosecute this application and transact all business in the Patent and Trademark office connected therewith:

Name	Registration No.	Associate Power of Attorney Attached [ ] Yes [ ] No
Jacobus C. Rasser	37,043	
Donald E. Hasse	29,387	
T. David Reed	32,931	
Eileen L. Hughett	34,352	
Timothy B. Guffey	41,048	
Emelyn L. Hiland	41,501	

SEND CORRESPONDENCE TO:

T. David Reed, c/o The Procter Gamble Company			(513) 627-7025
Name			Phone No.
5299 Spring Grove Avenue	Cincinnati	Ohio	45217-1087
Street	City	State	Zip Code

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor: BOTTOMLEY, Ian

Inventor's signature Ian Bottomley Date 10<sup>th</sup> April 2000

Residence: 17 howick Street Alnwick, Northumberland NE66 1UZ GB

Citizenship: GB

Post Office Address: 5299 Spring Grove Ave., Cincinnati, Ohio 45217-1087

Full name of second joint inventor, if any: COATES, David

Inventor's signature David Coates Date 10<sup>th</sup> April 2000

Residence: 14 Percy Road Shilbottle, Northumberland NE66 2HF GB

Citizenship: GB

Post Office Address: 5299 Spring Grove Ave., Cincinnati, Ohio 45217-1087

Full name of third joint inventor, if any: GRAYDON, Andrew Russell

Inventor's signature Andrew Russell Graydon Date 15<sup>th</sup> February 2000

Residence: 42 The Wills Bldg. Wills Oval, Newcastle-upon-Tyne NE7 7RW GB

Citizenship: GB

Post Office Address: 5299 Spring Grove Ave., Cincinnati, Ohio 45217-1087

Full name of fourth joint inventor, if any: JAMIESON, David McCrory

Inventor's signature David McCrory Jamieson Date 24<sup>th</sup> February 2000

Residence: 4 The Orchard, Hepscott Northumberland NE61 6HT GB

Citizenship: GB

Post Office Address: 5299 Spring Grove Ave., Cincinnati, Ohio 45217-1087



5-0-0  
Full name of fifth joint inventor, if any: MANCEL, Claude Paul

Inventor's signature *Claude Mancel* Date March 20, '00 X

Residence: Ave. Bellevue 115 1410 Waterloo BE

Citizenship: FR

Post Office Address: 5299 Spring Grove Ave., Cincinnati, Ohio 45217-1087 BEX

6-  
Full name of sixth joint inventor, if any: STODDART, Barry

Inventor's signature *Barry Stoddart* Date 15<sup>th</sup> February 2000

Residence: 364 Durham Road, Low Fell Gateshead NE9 5AP GB GBX

Citizenship: GB

Post Office Address: 5299 Spring Grove Ave., Cincinnati, Ohio 45217-1087